Navstar Global Positioning System

ALLSAT OPEN

Conference

Hannover, Germany

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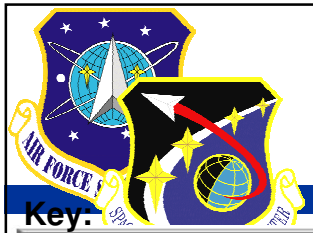
Overview

- Organization
- Program Status
- Modernization
- New Civil Signals
- Civil Signal Interoperability
- Summary

Navstar GPS JPO Organization



Key:

- Senior Leadership
- Functional
- Programs

SMC/GP
SPD (Col Ballenger)
Dep (Col Reaser)

- Dep, PM US Army GPA (LTC Matthews)
- Dep, PM DOT GPC (Mr Nagle)
- Dep, PM NGA GPD (Mr Creel)
- Dep, PM US Navy GPN (CDR Pietruszewski)

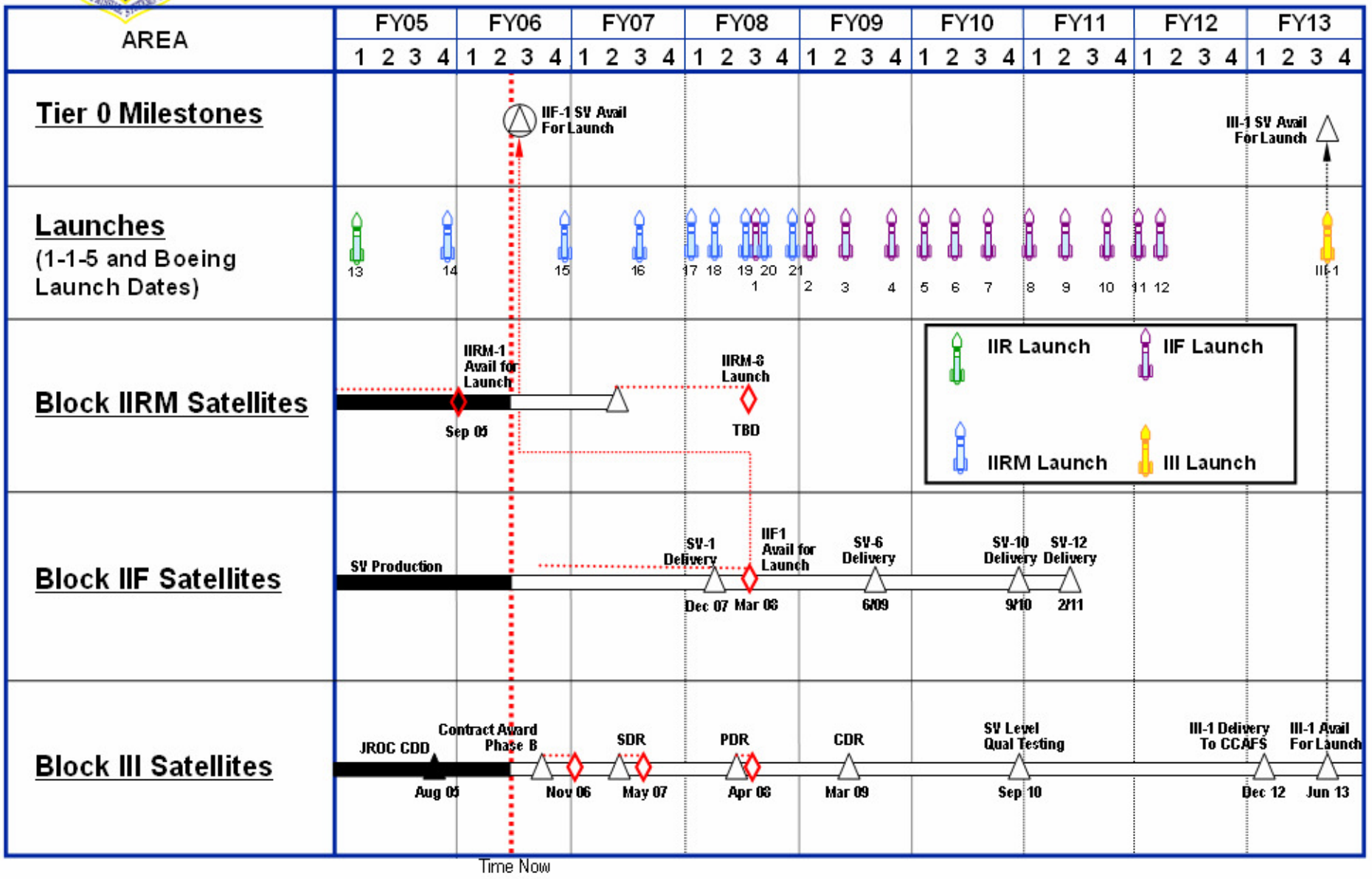
- Contract Management GPK (Ms Grubbs)
- Program Control GPP (Ms Suchomel)
- System Engineering GPE (Col Crews)
- Integrated Logistics GPL (Lt Col Hoover)
- Management Ops GPO (Mr Traversa)
- Control Segment Group GPG (Col Robinson)
- Space Segment Group GPH (Mr Dunn)
- User Equipment Group GPU (COL LoSchiavo)
- SSM for UE GPW (WRALC) (Mr Sartain)
- SSM–Peterson AFB GPG (Mr McIntyre)
- SATAF-Schriever AFB GPG (Lt Col Harms)
- NDS GPZ (Lt Col Boyson)

GPS Constellation Status

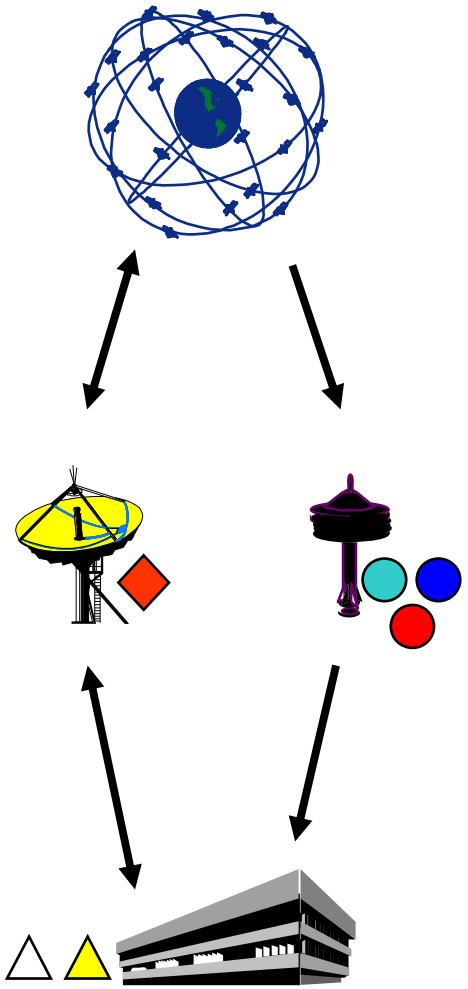
28 Operational Satellites
Baseline Constellation: 24

- 15 Block II/IIA satellites operational
- 12 Block IIR satellites operational
  - Modernizing 8 Block IIR satellites
- 1 GPS Block IIR-M operational
- Next launch – GPS IIR-14(M) (2nd IIR-M)
  - 14 Sep 06
- Global GPS civil service performance commitment met/exceeded since Dec 93

Space Segment Schedule



GPS Ground Control System



Master / Backup Control Stations
Provide navigation estimation (ephemeris and clock), control the satellites, control the operations network, and schedule missions

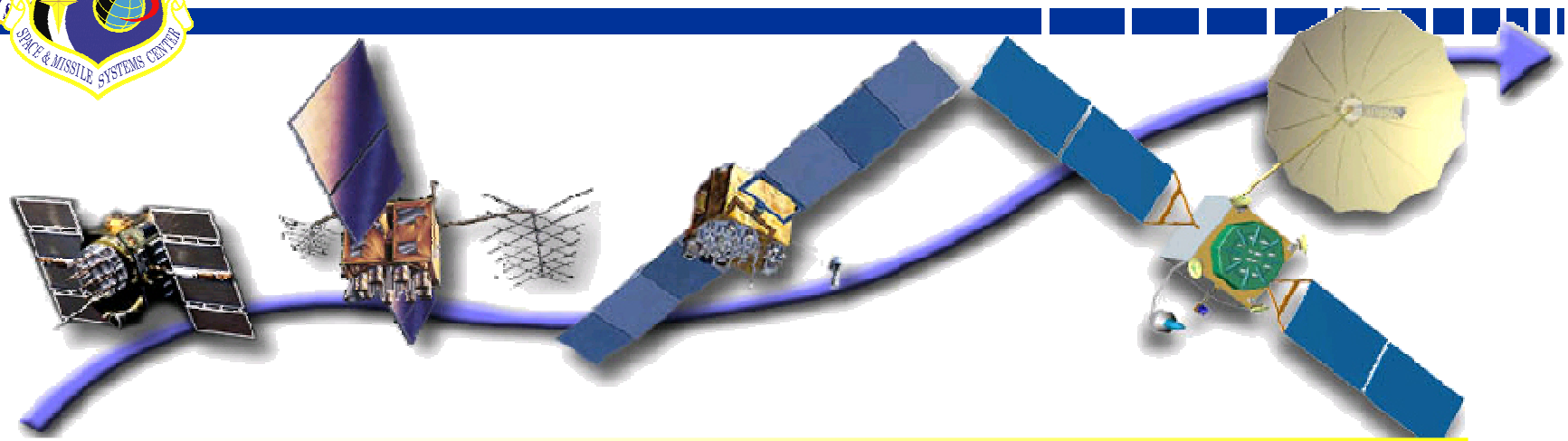
GPS / NGA monitor stations / upcoming NGA monitor stations
Monitor navigation messages to collect system performance metrics, collect environment data, send data to OCS to calculate accurate satellite uploads

Ground antennas
Transmit navigation data / commands and collect telemetry

Why Modernize?

- **Civil:**
  - **More robustness against interference**
  - **Compensation for ionospheric delays**
  - **Wide-laning/tri-laning – More precision**
  - **Interoperability - more signals in view**
- **Military:**
  - **Protection of friendly use**
  - **Prevention of adversary exploitation**
  - **Preservation of civil use outside area of operations**
- **Both:**
  - **More accuracy, availability, integrity, and reliability**

GPS Modernization Path



Increasing System Capabilities ◆ Increasing Defense / Civil Benefit

Block IIA/IIR

Basic GPS

- Std Service (16-24m SEP)
  - Single frequency (L1)
  - Coarse acquisition (C/A) code navigation
- Precise Service (16m SEP)
  - Y-Code (L1Y & L2Y)
  - Y-Code navigation

Block IIR-M, IIF

IIR-M: IIA/IIR capabilities plus

- 2nd civil signal (L2C)
- M-Code (L1M & L2M)
  - Eliminates SA for denial
- Anti-jam flex power

IIF: IIR-M capability plus

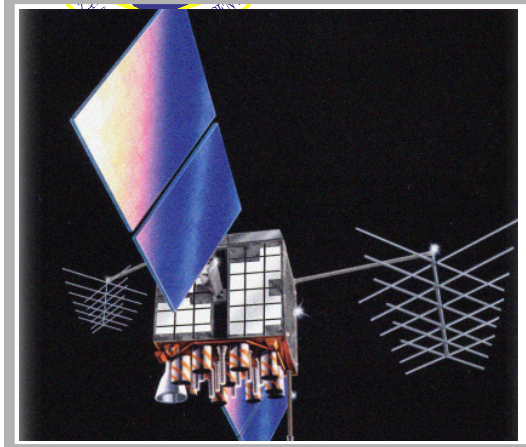
- 3rd civil signal (L5)
- Anti-jam flex power

Block III

Block IIIA:

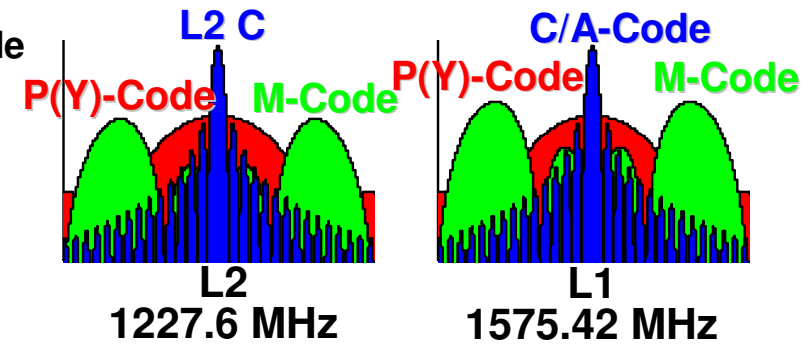
- Increased anti-jam power
- Increased security
- Increased accuracy
- Navigation surety
- Backward compatibility
- Assured availability
- Controlled integrity
- System survivability
- 4th civil signal (L1C)

GPS Signal in Space Modernization



Block IIR-Ms (SVs 14-21)
- Adds L2C to L2
- Adds new military M-Code
- Increase signal power
- Adds Flex Power

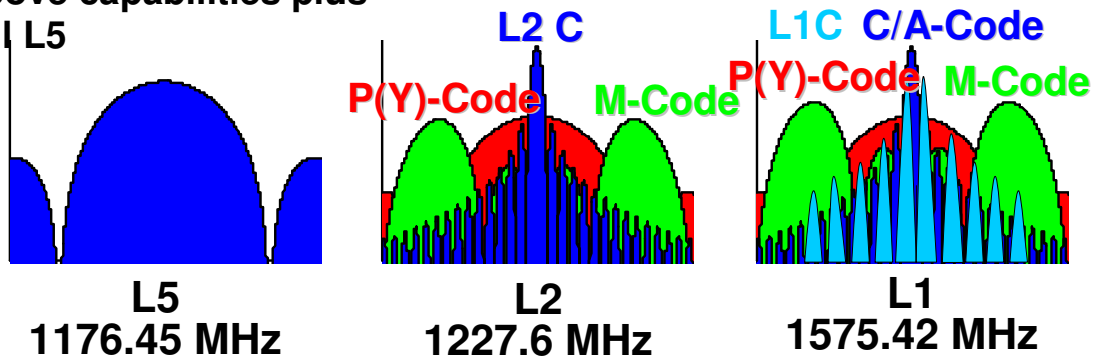
Signals in Space



- Increased accuracy
- Better anti-jam
- US ability to jam the enemy
- Simpler operations

Block IIFs
- All the above capabilities plus
- Adds civil L5

Block IIIA: Adds civil L1C

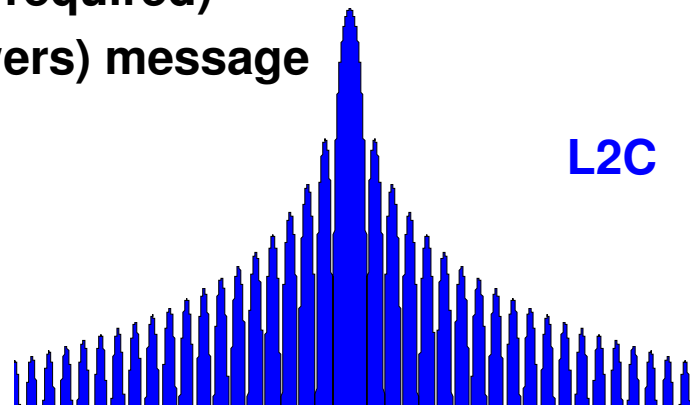


- M-Code is a critical enabler to meeting military challenge
- L1C and L5 are critical enablers to meeting civil challenge

Second Civil Signal (L2C)

- Civil users now get dual-frequency
- Better accuracy when combined with current civil GPS L1 C/A signal
- Less susceptible to interference—possible indoor use
  - Signal power split between data & data-less parts
  - Data-less part is a pilot carrier
    - Better tracking threshold
    - Eliminates ½ cycle phase ambiguities
  - Longer spreading codes
    - Reduce susceptibility to narrowband and cross-satellite interference
    - Resolve data timing ambiguity (no bit sync required)
  - Forward error correction (FEC) improves (lowers) message demodulation threshold
- CNAV data structure improves precision

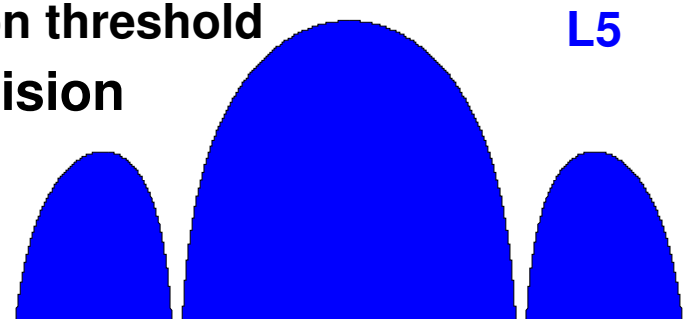
Signal defined in IS-GPS-200



Third Civil Signal (L5)

- Wider bandwidth
- Aeronautical Radionavigation Service Band
- Interoperable with Galileo's E5a
- Less susceptible to interference—possible indoor use
  - Higher power than L2C
  - Signal power split between data & data-less parts
  - Data-less part is a pilot carrier
    - Better tracking threshold
    - Eliminates ½ cycle phase ambiguities
  - Longer spreading codes
    - Reduce susceptibility to narrowband and cross-satellite interference
    - Resolve data timing ambiguity (no bit sync required)
  - FEC improves (lowers) message demodulation threshold
- CNAV decreases TTRM and improves precision

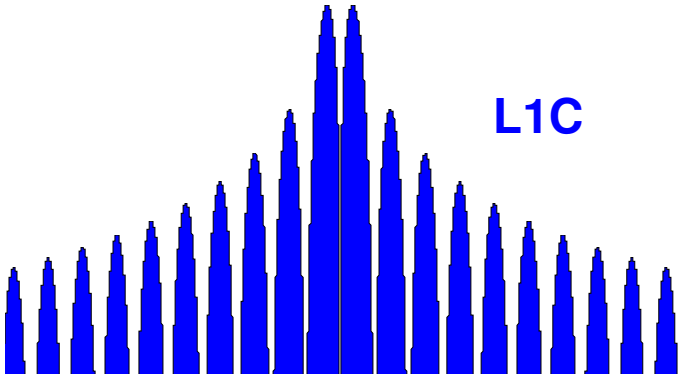
Signal defined in IS-GPS-705



Fourth Civil Signal (L1C)

- To be implemented on GPS Block III
- Internationally defined civil signal
  - Worldwide civilian community desired robust signal
- Improved code and carrier tracking
- CNAV-2 message structure
  - More powerful FEC further improves demodulation
  - Interleaving minimizes effects of short fades
- Aeronautical Radionavigation Service Band
- Common with Japan's QZSS
- Interoperable with Galileo's L1 OS
- Possibility for Russian GLONASS?

Signal defined in IS-GPS-800



L1C Basics

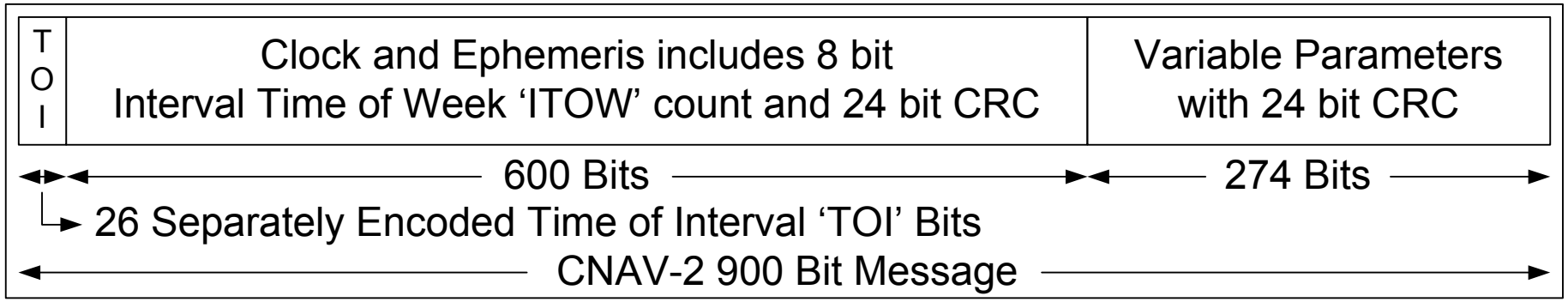
- **Waveform is BOC(1,1)**
  - **Baseline in the US/EU agreement**
  - **Good compatibility with other GPS signals**
  - **An alternative may be MBOC (described separately)**
- **Code length is identical on pilot carrier and message channel(s) so 100% of signal power can be used for acquisition (similar to L5)**
- **Secondary codes on pilot carriers**
  - **Defines message blocks before decoding data**
  - **Fixed message demodulation can start anywhere**
  - **Further improves protection against narrowband interference and cross-satellite interference**

L1C Detailed Characteristics

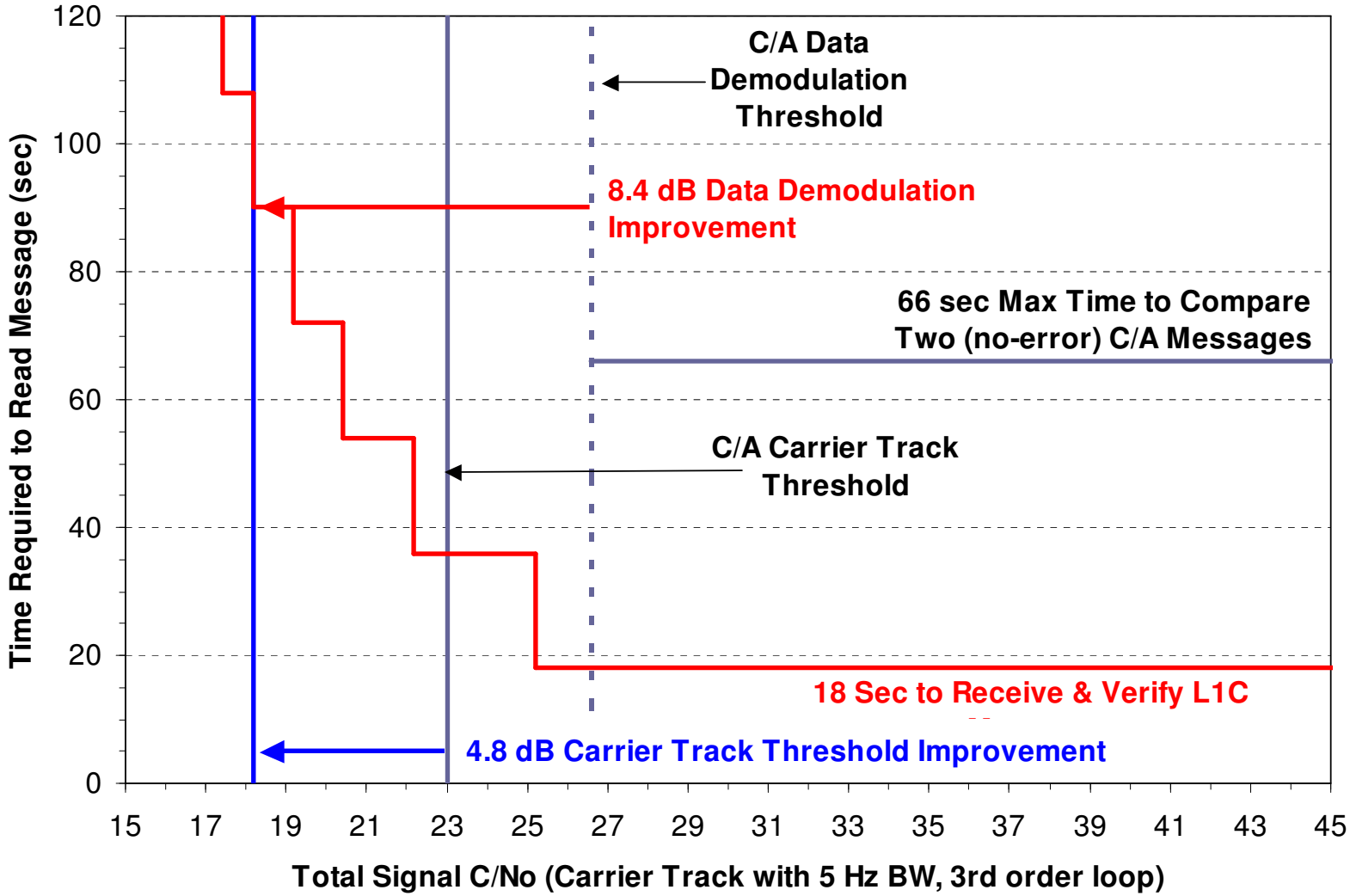
- Pilot carrier with 75% of L1C signal power
  - For 1.8 dB better code and carrier tracking
  - Or to track at 2.25 times higher acceleration
- Data rate = 50 bps; Symbol rate = 100 sps
  - Message length = 900 bits/50 bps = 18 sec
  - LDPC FEC block encoding
    - Message demodulation at 25.2 dB-Hz C/No (total signal)
    - Clock & Ephemeris bit combining down to track threshold
  - Symbol interleaving to mitigate brief signal losses
- Weil-based spreading codes
  - 10,230 chip base codes match data symbol length
  - Provides excellent correlation properties
  - 1800 chip pilot overlay code frames message

L1C Message Structure

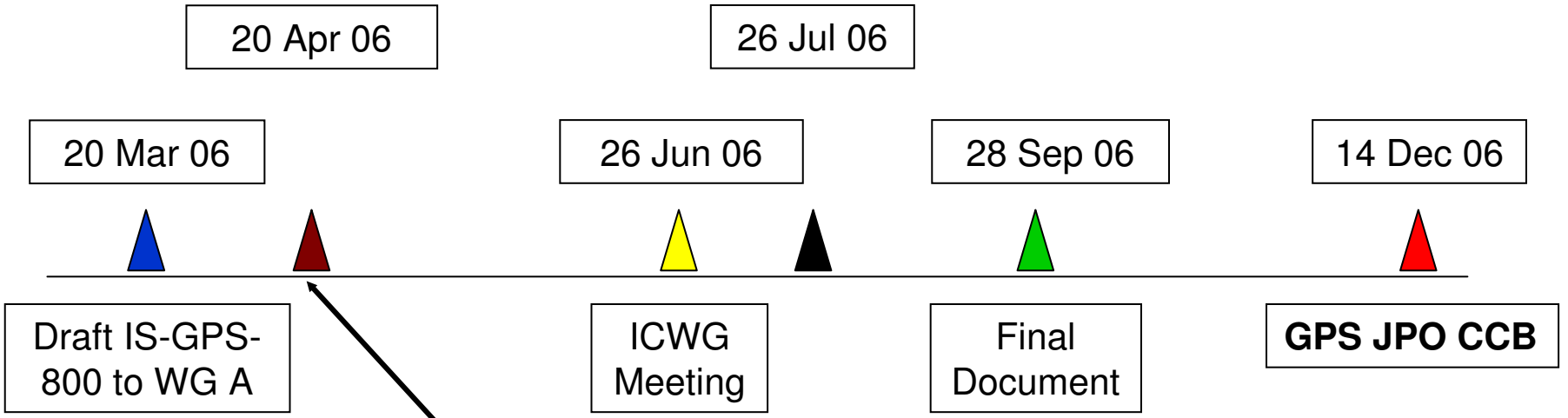
300 bit CNAV Type 10	300 bit CNAV Type 11	300 bit CNAV Type 3x



L1C - L1C/A Comparison



IS-GPS-800 Schedule



Draft IS-GPS-800 posted on schedule at:

http://gps.losangeles.af.mil/engineering/icwg/
http://www.navcen.uscg.gov/gps/modernization/default.htm
ftp://l1data@mavericks.gps.caltech.edu/ password = chestnut

Comparison

	L1 C/A	L2C	L5	L1C
Center Frequency	1575 MHz	1227 MHz	1175 MHz	1575 MHz
Modulation	BPSK	BPSK	BPSK	BOC
Chip Rate	1.023 Mcps	1.023 Mcps	10.23 Mcps	1.023 Mcps
Spreading Code	Gold	LFSR segment	Truncated Gold	Padded Weil
Data Rate	50 bps	25 bps	50 bps	50 bps
Message Structure	NAV	CNAV	CNAV	CNAV-2
Error Correction	None	Convolutional	Convolutional	LDPC
Other Features	Data Only	50/50 Pilot & Data	50/50 Pilot & Data Pilot & data overlay codes	75/25 Pilot & Data Pilot overlay code Bit Combining Interleaving
Target Users	All	High Precision	Aviation/High Precision	All

Improving civil system interoperability

	Characteristic	Interoperability Benefit
	• Common time and reference frames, or broadcast offsets	• Navigation solutions can blend measurements from different systems
Most Important for Future Interoperability	• Common carrier frequencies	• Common antenna and receiver front end—lower power and cost; common carrier tracking for higher accuracy
	• Similar spreading modulation spectra	• Common-mode dispersive errors removed in navigation solution for higher accuracy
	• Common spreading code lengths and common code family	• Lower crosscorrelation sidelobes for better weak-signal reception; common receiver processing for acquisition and tracking
	• Common data message structure and encoding	• Common receiver processing for data message decoding and processing

Current view of civil system interoperability

	Characteristic	Interoperability Benefit
GLONASS-GPS GLONASS-GALILEO GLONASS-QZSS	• Common time and reference frames, or broadcast offsets	• Navigation solutions can use measurements from different systems
	• Common carrier frequencies	• Common antenna and receiver front end—lower power and cost; common carrier tracking for higher accuracy
GPS-GALILEO QZSS-GALILEO	• Similar spreading modulation spectra	• Common-mode dispersive errors removed in navigation solution for higher accuracy
	• Common spreading code lengths and common code family	• Lower crosscorrelation sidelobes for better weak-signal reception; common receiver processing for acquisition and tracking
GPS-QZSS	• Common data message structure and encoding	• Common receiver processing for data message decoding and processing

Navstar GPS Program Summary

- **Sustaining constellation performance**
  - Planning for next GPS Block IIR-M launch
- **Modernizing by adding new signals & capabilities**
  - Launch out rest of Block IIR-Ms
  - First Block IIF launch in 2008
    - 24 L2C capable satellites projected in FY14
  - Field new civil and military GPS signals
    - Nailing down L1C technical design with Europe and Japan
- **Planning to execute for the next generation**
  - GPS Block III Space Vehicles
    - First Block IIIA launch in 2013
  - Next Generation Control System - OCX
  - Modernized Receivers

Any Time, Any Place - Right Time, Right Place